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**בקשה לפטנט**  
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אני, (שם המבקש, מענו ולגבי גוף מאוגד במקום התאגדותו)  
I, (Name and address of applicant, and in case of body corporate-place of incorporation)

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ד"ר אליעזר רוזנבלום  
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**שיטה ומערכת לגילוי אובייקט**

(בעברית)  
(Hebrew)

**An object detection method and system**

(באנגלית)  
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שיטה ומערכת לגילוי אובייקט

An object detection method and system

Rafael Armament Development Authority  
Ltd.

רפא"ל רשות לפתוח אמצעי לחימה בע"מ

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עזרא שמאי

**C. 133728**

## **An Object Detection Method and System**

### **FIELD OF THE INVENTION**

This invention is generally in the field of proximity sensing techniques, and relates to a method and system for monitoring a region of interest to detect an object therein.

### **5 BACKGROUND OF THE INVENTION**

Proximity sensing systems aimed at object detection in general are well known *per se* and are found in wide use in commercial, police and military applications. Generally, such systems fall into two broad categories of systems: “active” systems based on signal transmission towards an object and detection of  
10 signals returned (reflected) from the object, and “passive” systems that do not utilize energy transmission towards a target to be detected (e.g., infrared or heat-seeking systems).

US Patent No. 4,185,192 discloses a passive optical system utilizing two detectors oriented such that their optical axes and cone shaped fields of view  
15 intersect, thereby creating an overlapping region between these fields of view. By this, only those signals from the detectors, which are received simultaneously, being thereby indicative of that the detected light comes from the overlapping region, will cause the generation of a switching signal.

Another example of such a passive optical system for determining the  
20 presence of an object by utilizing the creation of a scene at the intersection of two optical paths associated with two detectors is disclosed in US Patent No. 4,317,992.

US Patent No. 4,396,945 discloses the technique that can be utilized in either an active or passive system for determining the position and orientation of an object in space. This technique is based on the determination of the intersection of a line with a plane or with another line.

5 Active systems are also disclosed in US Patents Nos. 4,590,410 and 4,724,480. According to the technique of US'410, which is aimed at detecting small objects, multiple light emitters and multiple light detectors are utilized. According to the technique of US'480, a system is composed of at least one projector generating a non-planar light and at least one camera, which are oriented  
10 such that the optical axes of the camera(s) and projector(s) intersect. By this, the projector associated with a first object and the region of intersection associated with a second object can be aligned.

## SUMMARY OF THE INVENTION

There is a need in the art to facilitate the detection of an object in a region of  
15 interest by providing a novel method and system for monitoring a region of interest.

The main idea of the present invention consists of defining a detecting window of a known location containing a region of interest to be monitored so as to detect objects located solely within the detecting window, and prevent monitoring of regions outside the detecting window. This is implemented by transmitting  
20 incident radiation towards the region of interest with a certain transmitting angle so as to define a plane of propagation of the incident radiation, and collecting radiation with a solid angle of collection intersecting with this plane. The detecting window is thus a plane-like region of intersection between the angle of collection and the plane of transmission. In order to optimally use the energy and maximize  
25 the signal-to-noise ratio (SNR) in detected radiation, the incident radiation is transmitted towards the region of interest with a certain predetermined angular intensity distribution.

It should be understood that the term "*monitoring*" used herein signifies observing or sensing the region of interest either to simply detect the appearance or

existence of an object within the detecting window (region of interest), or to enable imaging of the region of interest. For example, a detector may be of that kind producing generated data indicative of the detected reflections in the form of an indication signal (alarm) indicative of the fact that an object exists in the detecting  
5 window. To enable the imaging of an object located within the detecting window, an appropriate detector (i.e., having a sensing surface in the form of one- or two-dimensional array of pixels) and an image processing technique should be used.

There is thus provided, according to one aspect of the present invention, a  
10 method for monitoring a region of interest, the method comprising the steps of:

- (i) transmitting incident radiation towards the region of interest with a certain transmitting angle to define a plane of propagation of the incident radiation, and with a predetermined angular intensity distribution of the incident radiation, the region of interest being  
15 located within said plane;
- (ii) collecting reflections of the incident radiation with at least one solid angle of collection intersecting with said plane, a region of intersection being a detecting window of a predetermined geometry containing at least a portion of said region of interest;
- 20 (iii) detecting the collected radiation coming from within said detecting window and generating output signals indicative thereof.

Preferably, to provide the predetermined angular intensity distribution of the incident radiation, a transmitter unit comprises a specifically designed beam-shaping element.

25 Preferably, in order to increase the quality of detection, the sensitivity distribution of a receiver unit within the sensing surface of a detector is adjusted so as to provide substantially uniform output of the receiver unit for collected radiation components coming from different locations within the detecting window. Additionally, the sensing surface of the receiver unit can be divided into a plurality

of spatially separated sensing regions, each for collecting a corresponding one of the solid angle segments of the collection angle of the receiver unit.

According to another aspect of the present invention, there is provided a system for monitoring a region of interest, the system comprising:

- 5 (a) a transmitter unit operable to transmit incident radiation with a certain transmitting angle defining a plane of propagation of the incident radiation, and with a predetermined angular intensity distribution of the incident radiation, said region of interest being located within said plane; and
- 10 (b) at least one receiver unit oriented and operable to collect reflections of the incident radiation with at least one certain solid angle of collection intersecting with said plane, a region of intersection being a detecting window of a predetermined geometry containing at least a portion of said region of interest, to detect the collected radiation coming from
- 15 within said detecting window, and generate data indicative thereof.

Preferably, in order to prevent stray light (particularly, solar radiation) from reaching the receiver unit, and prevent the reflection of the incident radiation from the ground, the receiver and transmitter units are oriented such that the field of view of the receiver, while being directed towards the detecting window, extends

20 downwards from the horizon, and the incident radiation, while propagating towards the detecting window, is directed upwards from the horizon. For the same purpose, namely, to prevent the stray light from being detected, an additional receiver unit can be used to collect the reflections of the incident radiation coming from within the detecting window, but with a different collection angle. For example, the two

25 receivers are oriented such that their collection angles are symmetrical with respect to the detecting window plane. This arrangement prevents the direct solar radiation from being detected simultaneously by the two receiver units.

Generally, more than one receiver units may be provided being associated with the same transmitter unit and being operable for receiving radiation

30 components propagating with a corresponding one of solid angle segments of said



solid angle of collection. More than one transmitter units may be provided associated with a corresponding number of the receiver units, thereby monitoring the corresponding number of portions (detecting windows) of the region of interest.

The transmitter unit comprises a radiation source (preferably a laser diode) generating the incident radiation of a predetermined spectral range, a collimator, and a beam-shaping element providing the desired angular intensity distribution of the incident radiation. The beam-shaping element is of a refractive type, and is composed of one or more refractive blocks. Each of the refractive blocks has a first active surface facing the radiation source, a second active surface and an active medium enclosed between the first and second surfaces, and is formed by an array of facets. The orientation of a surface region of the first active surface defined by the facet with respect to the second active surface and a length of this surface region are defined by the angular intensity distribution of the incident radiation to be created by the radiation propagation through this specific facet.

Thus, according to yet another aspect of the present invention, there is provided a beam-shaping element for use in a transmitter unit for transmitting radiation with a predetermined angular intensity distribution, wherein

- the beam-shaping element comprises at least one refractive block having a first active surface for facing a radiation source of the transmitter unit, a second active surface and an active medium enclosed therebetween;
- the first active surface of said at least one refractive block is formed by an array of facets, orientation of a surface region of the first active surface defined by each of the facets with respect to the second active surface and a length of said surface region being defined by the predetermined angular intensity distribution,  $I(\theta)$ , of the transmitted radiation to be produced by radiation propagation through said at least one refractive block,  $\theta$  being a steering angle created by the facet of the refractive block.

Preferably, the beam-shaping element is also designed so as to be very robust to linear intensity variation of the emitted radiation at the entrance of the

beam-shaping element (at the first active surface). To this end, the array of facets is composed of two sets, which are symmetrically identical with respect to the central axis of the refractive block.

The receiver unit comprises a spectral filter preventing the detection of  
5 radiation outside said predetermined frequency spectral range, a radiation collecting assembly and a detector. A sensing surface of the detector has a predetermined geometry selected in accordance with the geometry of the detecting window (region of interest). The detector is implemented with a specifically constructed variable sensitivity filter, such that the output of the detector is substantially  
10 uniform for the collected reflections coming from different locations in the detecting window. This filter also reduces the overall stray light (background radiation) and back-scattered radiation from particles that may occasionally exist in the detecting window and scatter light towards the receiver unit.

Thus, according to yet another aspect of the present invention, there is  
15 provided a detector for use in a system for monitoring a region of interest, the detector comprising a radiation collecting assembly, and a sensing surface for receiving collected radiation and generating output representative thereof, wherein the sensing surface has a desirably variable sensitivity distribution such that the output signals corresponding to the collected radiation components coming from  
20 different locations within said region of interest are substantially equal.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

25 **Fig. 1** is a schematic illustration of the main components of a system according to the invention;

**Fig. 2** illustrates the construction of a transmitter unit of the system of Fig. 1;

**Figs. 3a to 3c** more specifically illustrate the features of a beam-shaping element of the transmitter unit of Fig. 2;

**Fig. 4** illustrates the construction of a receiver unit of the system of Fig. 1; and

5        **Fig. 5** more specifically illustrates the geometry of a sensing surface of the receiver unit given in an enlarged scale.

## DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, there is illustrated a system **10** according to the invention for monitoring a region of interest **12**, namely, for detecting the  
10 appearance or existence of an object within this region (detecting window). The system **10** comprises such main constructional parts as a transmitter unit **14** for generating incident radiation (light) and transmitting it towards the region of interest **12** (detecting window), and a receiver **16** unit for receiving reflections of the incident radiation coming from the region of interest **12** and generating data  
15 indicative thereof.

The transmitter unit **14** generates an incident light beam  $L_{inc}$  of a predetermined spectral range and transmits it with a certain acute angle of propagation  $\theta$  and certain angular intensity distribution of the incident light. The incident light beam has a substantially plane shape (the so-called "sheet of light"),  
20 and the region of interest **12** is located in this plane **P**. The receiver unit **16** collects light  $L_{col}$  (of the predetermined spectral range) with a solid angle of collection  $\phi$ .

The detecting window **12** presents a region of intersection between the plane **P** (defined by the transmitter unit **14**) and the solid angle of light collection  $\phi$  (defined by the receiver unit **16**). In other words, the detecting window **12** is a  
25 region cut by the solid angle of light collection  $\phi$  from the plane **P**. In the present example, the solid angle of collection  $\phi$  has a rectangular cross-section, thereby defining a rectangular shape of the detecting window **12**.

It should be understood that what the receiver unit **16** actually receives are reflections of the incident light produced within a region defined by the detecting window **12** (i.e., light reflected from an object located within the window **12**). The system **10** is thus capable of monitoring the detecting window containing the region  
5 of interest, i.e., detecting, and possibly also imaging, objects located within the detecting window **12**, while not detecting any object located outside this window.

With regard to the preferred relative position of the transmitter and receiver units, the following should be noted. The receiver unit **16** is oriented such that its field of view, while being directed towards the detecting window **12**, extends  
10 downwards from the horizon. The transmitter unit **14** is oriented such that the incident radiation, while propagating towards the detecting window **12**, is directed upwards from the horizon.

The above positioning of the transmitter and receiver units **14** and **16** is associated with the following. On the one hand, when stray light (in particular, the  
15 solar radiation) directly reaches the sensing surface of a detector, it causes the saturation of the detector. On the other hand, the reflections of incident laser radiation from the ground can reach the sensing surface of a detector, thereby causing a false alarm thereof. By locating the transmitter and receiver units in the above-described manner, the solar radiation is prevented from reaching the detector  
20 (irrespective of the current location of the Sun), and the incident radiation is prevented from reaching the ground.

It should be noted, although not specifically shown, that, in order to prevent the stray light from being detected, the system may comprise an additional receiver unit constructed similar to the receiver unit **16**, but oriented to collect the  
25 reflections of the incident radiation coming from within the detecting window **12** symmetrical to that of the unit **16** with respect to the detecting window plane. This arrangement prevents the direct solar radiation from being detected simultaneously by the two receiver units.

Generally, the system may comprise more than one receiver unit associated  
30 with the same transmitter and operable together to collect the reflections of the

incident radiation from the detecting window with the solid angle of light collection  $\phi$ . In this case, each of the receiver units collects a light component propagating with a corresponding one of the angular segments of the entire solid angle of light collection  $\phi$ .

5 It should also be noted that, in order to monitor the entire region of interest, the system may comprise more than one transmitter unit, each being associated with one or more receiver unit. In this case, each transmitter-receiver arrangement is associated with a corresponding one of the detecting windows that cover together the entire region of interest. In other words, the entire region of interest can be  
10 monitored by dividing it into a number of detecting windows, and detecting the reflections coming therefrom by the corresponding number of the transmitter-receiver arrangements.

Fig. 2 illustrates the main constructional elements of the transmitter unit 14. The transmitter unit 14 is composed of a laser diode (radiation source) 18 operating  
15 with the predetermined spectral range, an aspheric collimating lens 20, and a beam-shaping element 22. A light beam  $B_1$  emitted by the laser diode 18 is collimated by the lens 20, and the passage of collimated light  $B_2$  through the element 22 produces the incident sheet of light  $L_{inc}$ . It should be understood that the light propagation is shown here schematically, in order to simplify illustration.

20 For the purposes of the present invention, the beam-shaping element 22 is of a refractive type, having two active surfaces 22a and 22b enclosing an active medium  $M$  with the refraction index  $n$  therebetween. The element 22 is formed of one or more blocks, five such blocks, generally at 23, being shown in the present example. By using two active surfaces, the maximum angle of propagation of the  
25 incident radiation produced by the beam-shaping element can be increased. The beam-shaping element 22 is designed using a specific algorithm, so as to provide desired angular intensity distribution of the incident light. Additionally, the beam-shaping element is designed so as to be very robust to laser intensity variations. As for the aspherical collimating lens 20, its design is optimized for  
30 actual laser junction to achieve maximum collimation capability.

Turning now to Figs. 3a-3c, there are illustrated the main principles underlying the design of the beam-shaping element 22. In Fig. 3a, one block 23 of the element 22 is exemplified. The block 23 is composed of  $2N$  facets formed by two sets of facets (point-like locations)  $F$  and  $F'$ , each set consisting of  $N$  facets, and the sets being identically symmetrical with respect to the central axis CA of the block 23. Thus, the set  $F$  is composed of  $N$  facets  $F_i$  (where  $i=1, \dots, N$ ), and the identically symmetrical set  $F'$  is composed of  $N$  facets  $F'_i$  (where  $i=N+1, \dots, 2N$ ).

Fig. 3b illustrates the light propagation through one of the facets  $F_i$ . The emitted collimated light beam  $B_2$  impinges onto the surface region 22a defined by the facet  $F_i$  at an angle  $\varphi_i$ , successively passes through the medium  $M$  and the interface defined by the second active surface 22b of the facet  $F_i$ , and ensues from the facet  $F_i$  as the light component  $L_{inc}^{(i)}$  of the output incident light  $L_{inc}$  with the specific angle of propagation  $\theta_i$  (i.e., the angular segment of the acute angle of propagation  $\theta$  of the incident light). The projection  $d_i$  of the surface 22a onto the plane of the other active surface 22b that actually defines the length of the facet  $F_i$ , is determined in accordance with the light intensity  $I(\theta_i)$  which should be produced by the light propagation through this facet.

Considering the entire block 23 composed of  $2N$  facets  $F_i$ , each angle  $\varphi_i$  will have its corresponding angle  $\theta_i$ , and, accordingly, the angular intensity distribution  $I(\theta)$  of the incident light is formed by the intensities of the  $2N$  light components passed through the  $2N$  facets of the block 23, i.e.,  $I(\theta_i)$ .

Fig. 3c illustrates the angular intensity distribution as produced by the entire block 23 formed by symmetrically-identical facet-sets  $F_i$  and  $F'_i$ .

Thus, in order to provide certain desired angular intensity distribution of the incident light, the facets of the block of the beam-shaping element should be designed accordingly. The algorithm underlying the above design of the block of the beam-shaping element 22 consists of the following. The desired output angular intensity distribution of block 23,  $I(\theta)$ , is quantized into a discrete set of angles  $\theta_i$ ,

each angle defining the tangential of the first active surface **22a** which can be found by solving the following transcendental equation:

$$\theta_i = \arcsin[n \sin(\varphi_i - \arcsin(\frac{\sin \varphi_i}{n}))] \quad (1)$$

5 wherein  $\theta_i$  is the specific angle of propagation of light ensuing from the facet for which the tangential  $\varphi_i$  must be found.

Taking into account that the length  $d_i$  of the corresponding facet  $F_i$  for each angle  $\theta_i$  is proportional to the relative output intensity at that angle  $I(\theta_i)$ , each facet  $F_i$  of the block **23** is calculated. By this, the desired angular intensity distribution of  
10 light ensuing from the beam-shaping element can be obtained.

In order to make the angular intensity distribution of the transmitter unit substantially independent of the linear non-uniformity of the laser diode radiation, the two sets  $F$  and  $F'$  of successive facets (i.e.,  $F_1, F_2, \dots, F_N$ , and  $F_{N+1}, F_{N+2}, \dots, F_{2N}$ ) are identically symmetrical with respect to the central axis  $CA$  of the block **23**.  
15 This is implemented by rotating each facet in one set the angle of  $180^\circ$  with respect to its corresponding facet in the other set (i.e.,  $F_1$  and  $F_{2N}$ ,  $F_2$  and  $F_{2N-1}$ , ...,  $F_N$  and  $F_{N+1}$ ).

The above technique dramatically increases the robustness of the element **22** to the possible linear intensity variation in the laser **18**, thereby providing  
20 substantially non-sensitivity of the incident light produced by the transmitter unit to any linear intensity variation of light emitted by the laser at the entrance to the beam-shaping element (i.e., at the surface **22a**).

It should be noted that in order to further increase the robustness of the beam-shaping element to intensity variations, the entire arrangement of  $2N$  facets  
25 (block **23**) can be scaled and periodically repeated. The scaling factor and number of periods solely depends on the quality of the laser **18**: the less the uniformity of light distribution emitted by the laser, the lower scale and greater number of periods should be used.

Fig. 4 illustrates the main components of the receiver unit **16**, which is of a pseudo-imaging kind. The receiver unit **16** comprises an optical system **30** (constituting a radiation collecting assembly), a detector **32**, and a protective window **34** accommodated in front of the optical system **30** (with respect to the direction of propagation of light impinging onto the receiver unit), all being accommodated in a metal housing **36**. The optical system **30** is composed of a lens assembly **38** and a laser wavelength matched spectral filter **40** accommodated in front of the lens assembly **38**. The lens assembly **38** includes a first aspherical lens **38a** and a second spherical lens **38b** (with respect to a direction of propagation of the collected radiation through the receiver unit), which are mounted adjacent to each other and define a common optical axis **OA** of light propagation within the receiver unit towards a sensing surface **32a** of the detector **32**.

The receiver unit **16**, having the above design of the optical system **30**, is capable of providing a very large field of view and depth of focus, to meet the requirements of the imaging system. The optical system **30** is capable of creating an image of the detecting window (**12** in Fig. 1) on the sensing surface **32a**. Angular imaging resolution may vary over the field of view in order to provide the uniform spatial resolution of the detecting window.

The sensing surface **32a** of the detector **32** is specifically designed so as to provide a desired sensitivity distribution within the sensing surface **32a** of the detector resulting in substantially uniform output from different points on the sensing surface. This is associated with the fact that the design of the detecting window (i.e., its orientation with respect to the optical axis **OA**) may result in that the detected light components coming from locations (points) in the detecting window differently distanced from the plane of the sensing surface **32a**, will have different intensities. Hence, to provide uniform output signals from the detector **32**, a specifically constructed variable sensitivity filter should be implemented in the detector **32**.

As shown in Fig. 5, illustrating the sensing surface **32a** in an enlarged scale, the shape of the sensing surface **32a** is selected in accordance with the shape of the



detecting window 12 by projecting the contours of the detecting window 12 onto the sensing surface 32a through the optical system 30 of the receiver unit 16. In the present example of the rectangular-shaped detecting window 12, the projection of the points  $P_1$ - $P_4$  results in points  $P_1'$ - $P_4'$ , forming the trapezoid shape of the sensing surface 32a.

It should be noted, although not specifically shown that, in order to increase the depth of focus, the detector 32 should be oriented such that its sensing surface 32a is not perpendicular to the optical axis OA of the optical system 30, but rather appropriately inclined thereto. The angle of inclination can be determined by any suitable technique, for example, by the least square method, which is known *per se*.

To enable the light detection with substantially uniform output of the detector, the inventors have developed an interaction algorithm for the calculation of the sensitivity filter function to provide desirably variable sensitivity of the detector. This algorithm consists of the following:

It is known that, in the first approximation, the transmission function of the filter  $T_1(x,y)$  can be calculated based on the following formula:

$$T_1(x,y) = c \cdot \frac{R_1 \cdot R_2^2}{I(\theta(\bar{R}_1))} \quad (2)$$

wherein  $x$  and  $y$  are the coordinates in the filter plane, i.e., the sensing surface 32a;  $\bar{R}_1$  is a vector connecting the transmitter unit 14 with a specific point in the detecting window 12;  $I(\theta(\bar{R}_1))$  is the intensity of a signal generated by the transmitter unit 14 and transmitted in the  $\bar{R}_1$  direction;  $\bar{R}_2$  is a vector connecting the specific point in the detecting window 12 with the receiver unit 16; and  $c$  is a normalization factor chosen to achieve maximum overall transparency.

The above equation (2), however, does not take into account the actual point spread function (PSF) of the system, which should be taken into account when

dealing with the performance of a real system. In this case (i.e., considering the PSF), the intensity distribution  $I_I$  of the detector output reads:

$$I_1(x_d, y_d) = \iint_{\substack{\text{over the} \\ \text{detector} \\ \text{plane}}} T_1(x, y) P(x - x_d, y - y_d) dx dy \quad (3)$$

5 wherein  $P(x - x_d, y - y_d)$  is the actual PSF of the optics of the receiver unit,  $(x_d, y_d)$  being the coordinates of a current location in the detector plane (sensing surface 32a).

Thus, for each point in the detecting window 12, the corresponding PSF on the detector plane 32a can be found by using the known available ray-tracing code. In the present example, the OSLO SIX software product commercially available from Sinclair Optics Inc., USA was used. Other known codes, such as Zemax or Code V, can be used. Then, this PSF is multiplied by  $T_1(x, y)$  and numerically integrated over the entire detector plane, thereby producing an actual signal on the detector (equation (3) above).

15 This process is repeated for an appropriate grid of points in the detecting window 12, thereby producing the sensitivity map on the detector plane 32a. If PSF were an ideal impulse response, namely delta function, the map of sensitivity would be uniform. In practice, however, owing to the fact that the actual PSF is blurred by real optical system, a uniform sensitivity map cannot be obtained.

20 In order to achieve the uniform output of the detector, the desirably variable sensitivity map of the detector should be provided. To this end, the iteration algorithm is based on correcting (varying) the transmission function  $T_1(x, y)$  by normalizing it with respect to the calculated sensitivity map, thereby producing a new transmission function  $T_2(x, y)$ :

25

$$T_2(x_d, y_d) = \frac{T_1(x_d, y_d)}{I_1(x_d, y_d)} \quad (4)$$

This process is repeated until appropriate uniformity of the detector output is obtained. More specifically, for  $k$ -th level of iteration of the transmission function  $T_k(x,y)$  (i.e.,  $k$ -th step of the optimization procedure), the corresponding value of the intensity function  $I_k(x,y)$  is calculated as described above (equation (3)), and, accordingly, the next iteration level  $T_{k+1}(x,y)$  in the iteration procedure is found. The iteration procedure continues until the required uniformity of the detector output  $I(x,y)$  is achieved.

The simulations have shown that the iteration procedure converges very fast (about 5 iterations), producing quite uniform output from the detector (better than 5% P-V).

The above variable transmission (sensitivity) of the detector can be implemented by appropriately patterning the sensing surface 32a of the detector in different ways. For example, the pattern may be fabricated in a separate, specifically coated glass plate and placed on the sensing surface. Alternatively, the correspondent transmission filter (pattern) or the different sensitivity can be implemented directly on the detector by means of ion implantation of the detector's sensing surface (e.g., Si-B).

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the preferred embodiment of the invention as hereinbefore exemplified without departing from its scope defined in and by the appended claims.

**CLAIMS:**

1. A method for monitoring a region of interest, the method comprising the steps of:

- 5 (i) transmitting incident radiation towards the region of interest with a certain transmitting angle to define a plane of propagation of the incident radiation, and with a predetermined angular intensity distribution of the incident radiation, the region of interest being located within said plane;
- 10 (ii) collecting reflections of the incident radiation with a solid angle of collection intersecting with said plane, a region of intersection being a detecting window of a predetermined geometry containing at least a portion of said region of interest;
- (i) detecting the collected radiation coming from within said detecting window and generating output signals indicative thereof.

15 2. The method according to Claim 1, wherein said transmitting of the incident radiation provides propagation of the incident radiation upwards from the horizon, and said collecting is carried out with a field of view extending downwards from the horizon.

3. The method according to Claim 1, wherein the transmission of the incident  
20 radiation with the predetermined angular intensity distribution comprises the step of:

- passing radiation emitted by a radiation source through a beam-shaping element comprising at least one refractive block having a first active surface facing the radiation source, a second active surface, and an active  
25 medium enclosed therebetween, the first active surface of said at least one refractive block being formed by an array of facets, orientation of a surface region of the first active surface defined by each of the facets with respect to the second active surface and a length of said surface region being defined by the predetermined angular intensity distribution,

$I(\theta)$ , to be produced by radiation propagation through said at least one refractive block,  $\theta$  being a steering angle created by the facet of the refractive block.

4. The method according to Claim 3, wherein the orientation of the surface region of the first active surface defined by each of the facets with respect to the second active surface and the length of said surface region are determined as follows:

- the predetermined angular intensity distribution,  $I(\theta)$ , is quantized into a discrete set of angles  $\theta_i$ , each defining a tangential  $\varphi_i$  of said surface region by solving a following transcendental equation:

$$\theta_i = \arcsin[n \sin(\varphi_i - \arcsin(\frac{\sin \varphi_i}{n}))]$$

wherein  $\theta_i$  is a specific angle of propagation of radiation ensuing from the  $i^{\text{th}}$  facet;

- each of the facets is calculated taking into account that a projection of said surface region of each facet onto the second active surface is proportional to a relative output intensity at the corresponding angle.

5. The method according to Claim 3, wherein said array of facets of the refractive block is composed of two sets, which are symmetrically-identical with respect to a central axis of the refractive block.

6. The method according to Claim 1, wherein the detection of the reflections comprises the step of:

- providing desirably variable sensitivity distribution within a sensing surface of a detector, thereby providing substantially equal output signals of the detector irrespective of locations within the detecting window where the reflections are produced.

7. The method according to Claim 6, wherein the desirably variable sensitivity distribution is provided by forming the sensing surface with a pattern providing a desired sensitivity map within the sensing surface.

8. The method according to Claim 7, wherein said pattern is determined by performing an iteration algorithm for calculating a sensitivity filter function to be such as to provide substantially equal values of the output signals corresponding to the reflections of the incident radiation coming from different locations in the detecting window.  
5
9. The method according to Claim 8, wherein said iteration algorithm consists of determining, for each location in the detecting window, a corresponding value of PSF on the sensing surface; multiplying the determined PSF value by a transmission function  $T_1(x,y)$  of the filter, and numerically integrating it over the entire sensing surface; repeating the same for an appropriate grid of locations in the detecting window; and correcting the transmission function  $T_1(x,y)$  by normalizing it with respect to the calculated sensitivity map.  
10
10. The method according to Claim 1, wherein the collection of the reflections of the incident radiation comprises collection of components of the reflections of the incident radiation propagating with angular segments of said solid angle of collection.  
15
11. The method according to Claim 1, wherein the reflections of the incident radiation are collected with an additional solid angle of collection.
12. The method according to Claim 1, wherein the two solid angles of collection are symmetrically identical with respect to the plane of the detecting window.  
20
13. The method according to Claim 9, and also comprising the step of transmitting the incident radiation towards the region of interest with at least one additional transmitting angle and with a predetermined angular intensity distribution of the incident radiation, the additional transmitting angle intersection with the additional solid angle of collection in said plane, thereby defining at least two detecting windows locating in the same plane and containing at least two portions of the region of interest, respectively.  
25
14. A system for monitoring a region of interest, the system comprising:

(a) a transmitter unit operable to transmit incident radiation with a certain transmitting angle defining a plane of propagation of the incident radiation and with a predetermined angular intensity distribution of the incident radiation, said region of interest being located within said plane; and

(b) at least one receiver unit oriented and operable to collect reflections of the incident radiation with a certain solid angle of collection intersecting with said plane, a region of intersection being a detecting window of a predetermined geometry containing at least a portion of said region of interest, to detect the collected radiation coming from within said detecting window, and generate data indicative thereof.

15. The system according to Claim 14, and also comprising at least one additional receiver unit.

16. The system according to Claim 15, wherein said at least one additional receiver unit collects the reflections of the incident radiation with a solid angle of collection symmetrically identical to said certain solid angle of collection with respect to said plane.

17. The system according to Claim 14, wherein the transmitter unit is oriented such that the incident radiation propagates towards the detecting window upwards from the horizon, and the receiver unit is oriented such that its field of view extends downwards from the horizon.

18. The system according to Claim 14, wherein the transmitter unit comprises a radiation source, a collimator, and a beam-shaping element.

19. The system according to Claim 14, wherein said beam-shaping element is of a refractive type comprising at least one refractive block having a first active surface facing the radiation source, a second active surface, and an active medium with a certain refraction index enclosed therebetween, the first active surface of said at least one refractive block being formed by an array of facets, orientation of a surface region of the first active surface defined by each of the facets with respect to the second active surface and a length of said surface region being defined by the

predetermined angular intensity distribution,  $I(\theta)$ , to be produced by radiation propagation through said at least one refractive block,  $\theta$  being a steering angle created by the facet of the refractive block.

20. The system according to Claim 19, wherein said array of facets of the refractive block is composed of two sets, which are symmetrically identical with respect to a central axis of the refractive block.

21. The system according to Claim 19, wherein said beam-shaping element comprises at least one additional refractive block, scale and number of the refractive blocks depending on the distribution of radiation emitted by the radiation source within the first active surface of the beam-shaping element.

22. The system according to Claim 14, wherein the receiver unit comprises a spectral filter, a radiation collecting assembly, and a detector, which has a sensing surface with predetermined geometry and desirably variable sensitivity distribution.

23. The system according to Claim 14, wherein the sensing surface is divided into regions, each region receiving a corresponding one of solid angle segments of the solid angle of collection.

24. The system according to Claim 22, wherein the sensing surface is shaped and patterned in accordance with the geometry of the detecting window and its orientation with respect to an optical axis of propagation of the collected light.

25. The system according to Claim 22, wherein the geometry of the sensing surface is defined by a projection of the detecting window onto the sensing surface through said radiation collecting assembly.

26. The system according to Claim 22, wherein the sensing surface is made of silicone with a pattern formed by ion implantation of boron thereby providing desired distribution of a transmission function of the sensing surface.

27. The system according to Claim 22, wherein the sensing surface is covered with a mask providing desired distribution of a transmission function of the sensing surface.

28. A beam-shaping element for use in a transmitter unit for transmitting radiation with a predetermined angular intensity distribution, wherein



- the beam-shaping element comprises at least one refractive block having a first active surface for facing a radiation source of the transmitter unit, a second active surface, and an active medium enclosed therebetween;
- the first active surface of said at least one refractive block is formed by an array of facets, orientation of a surface region of the first active surface defined by each of the facets with respect to the second active surface and a length of said surface region being defined by the predetermined angular intensity distribution,  $I(\theta)$ , to be produced by radiation propagation through said at least one refractive block,  $\theta$  being a steering angle created by the facet of the refractive block.

29. A detector for use in a system for monitoring a region of interest, the detector comprising radiation collecting assembly, and a sensing surface for receiving collected radiation and generating output representative thereof, wherein the sensing surface has a desirably variable sensitivity distribution such that the output signals corresponding to the collected radiation components coming from different locations within said region of interest are substantially equal.

For the Applicants,  
**REINHOLD COHN AND PARTNERS**

By:



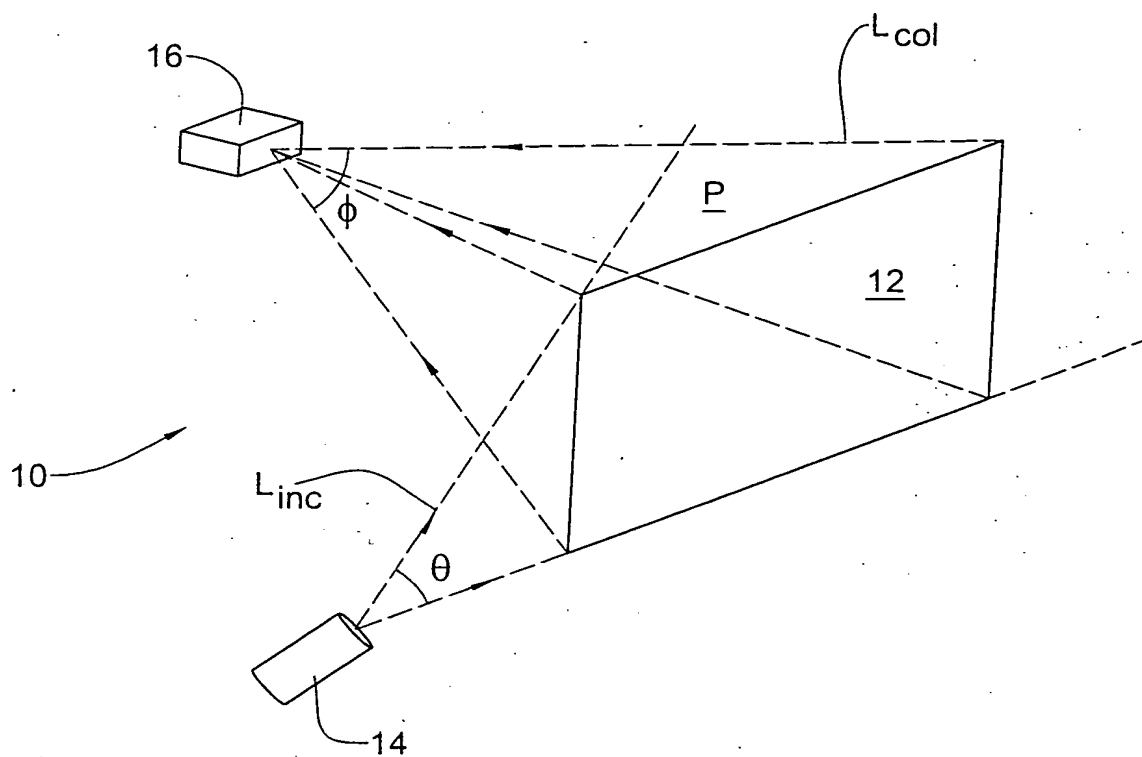


FIG. 1

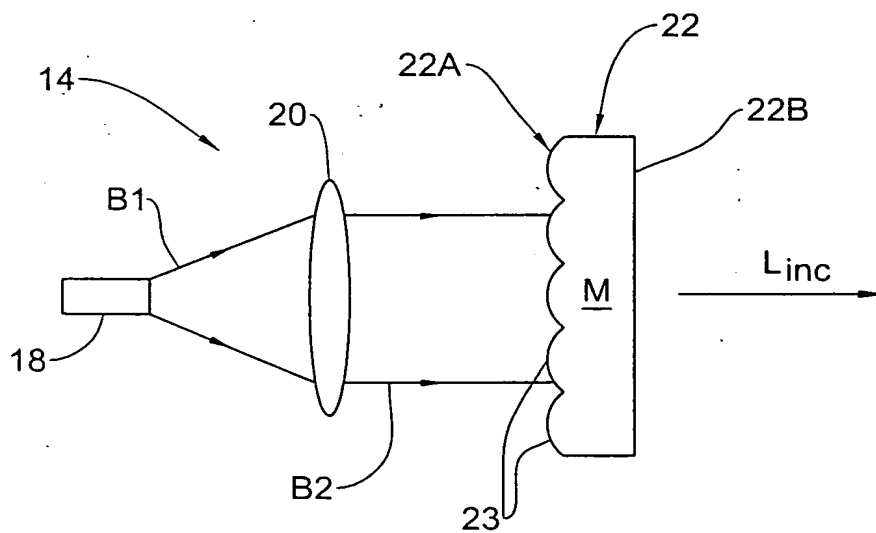


FIG. 2

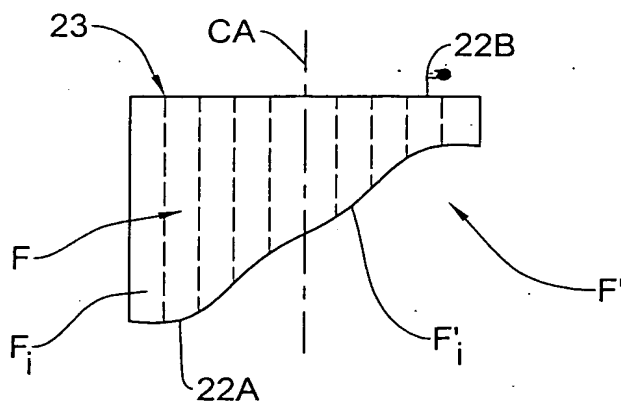


FIG. 3A

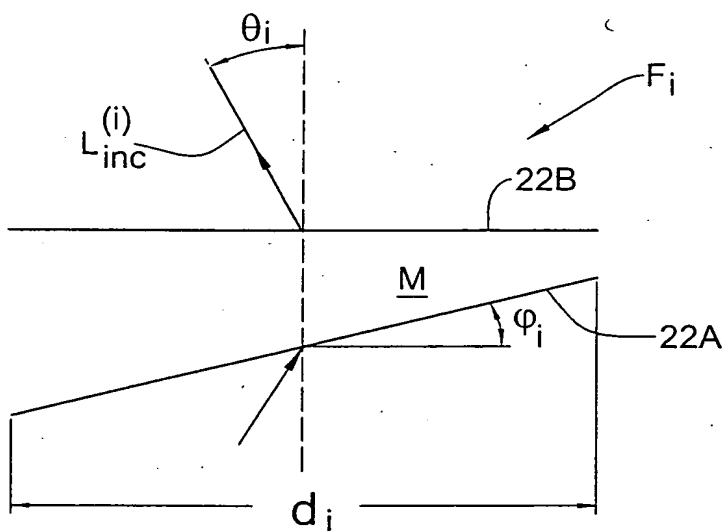


FIG. 3B

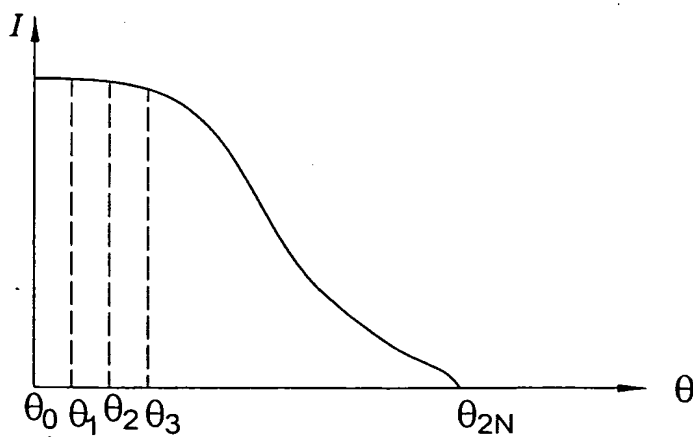


FIG. 3C

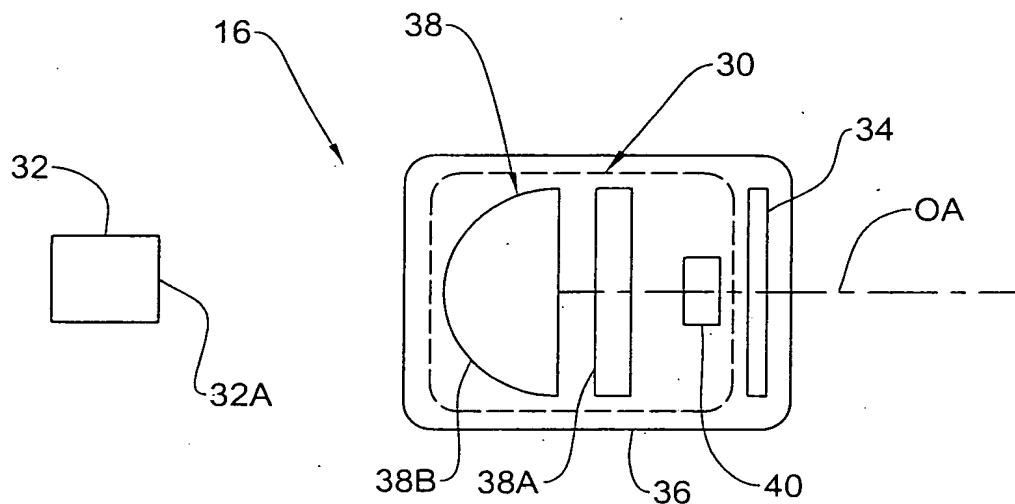


FIG. 4

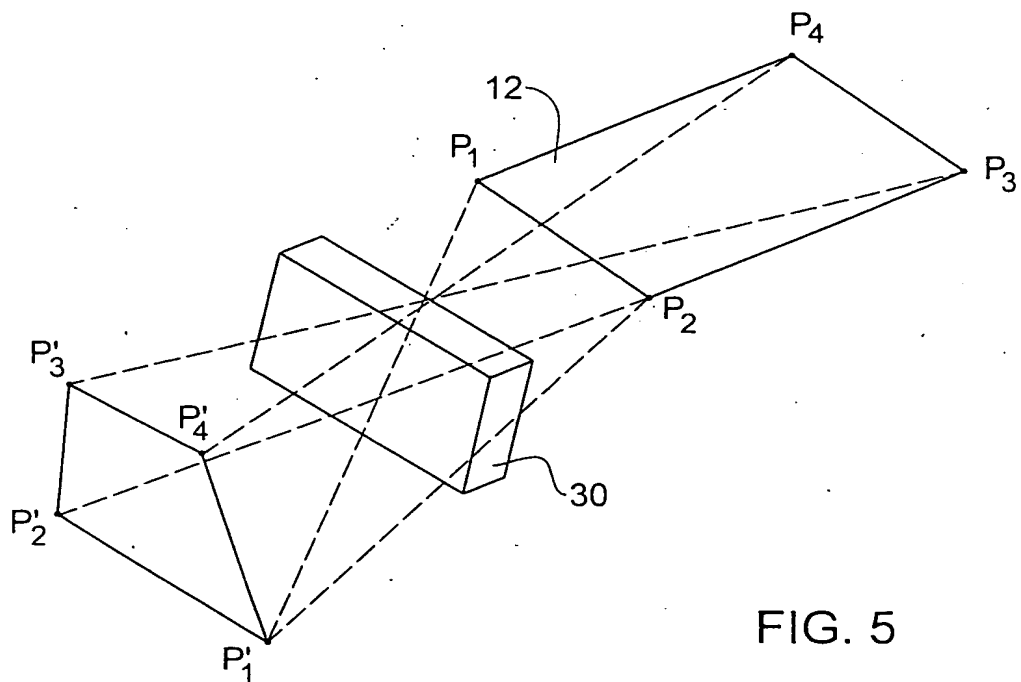


FIG. 5